

Transcoder and transcoding method with bit rate regulation

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Abstract

A transcoding system comprises a decoding unit for receiving coded data which has been obtained by subjecting image data of each coding unit to a coding process including a first orthogonal transform process and a first quantization process, and decoding the input coded data for each coding unit to generate decoded data; and an encoding unit for coding the decoded data to generate transcoded data. The decoding unit includes an inverse quantizer for inversely quantizing quantized coefficients obtained from the input coded data, with a first quantization step which has been used in the first quantization process. The encoding unit includes a frequency transform unit for subjecting the decoded data to a second orthogonal transform process to generate frequency-domain data; and quantization means for subjecting the frequency-domain data to a second quantization process with a second quantization step which is derived on the basis of the transcoded data and the first quantization step. Therefore, under the restriction on the target number of bits in the transcoding process, the quantization step of the second quantization process can be set so that the quantization error is minimized, considering the non-linear relationship between the bit rate in the transcoding process and the quantization distortion (quantization error). Thereby, an increase in the quantization error due to the transcoding process can be effectively suppressed under the restriction on the bit rate.

Data supplied from the esp@cenet database - I2

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FIELD OF THE INVENTION

[0001] The present invention relates to a coded data transform method, a transcoding method, and a transcoding system and, more particularly, to those for transforming coded data which has been obtained by subjecting a video signal to a coding process and stored in a data base or the like, into coded data which can be decoded by a receiver, according to a transcoding process using a coding method and coding parameters different from those of the coding process. The invention also relates to a data storage medium containing a program for executing the transcoding process by using software.

BACKGROUND OF THE INVENTION

[0002] In recent years, we have greeted the age of multimedia in which audio, video, and other data are integrally handled, and the conventional information media, i.e., means for transmitting information to men, such as newspapers, magazines, televisions, radios, and telephones, have been adopted as the targets of multimedia. Generally, "multimedia" means media in which, not only characters, but also diagrams, speeches, and especially images are simultaneously expressed in relation with each other. In order to handle the conventional information media as the targets of multimedia, it is necessary to express the information as data in digital formats (digital data).

[0003] When the quantity of data possessed by each of the above-described information media is estimated as the quantity of digital data, in the case of characters, the data quantity per character is only 1 SIMILAR 2 byte. However, in the case of speech, the data quantity is 64kbits per second (quality for telecommunication). Further, in the case of moving picture, the required data quantity is more than 100Mbits per second (quality for current television broadcasting). In other words, it is not practical to handle the digital data such as video data having an enormous quantity, as it is, in the corresponding information media. For example, although visual telephones have already been put to practical use by ISDN (Integrated Services Digital Network) having a transmission rate of 64kps SIMILAR 1.5Mbps, it is impossible to transmit digital video data corresponding to video output from a television camera as it is by ISDN.

[0004] So, data compression techniques are demanded. For example, for visual telephones, the video compression techniques based on the H.261 and H.263 standards which have been standardized by ITU-T (International Telecommunication Union - Telecommunication Sector) are employed. Further, according to the data compression technique based on MPEG1 standard, it is possible to record video data as well as audio data in an ordinary music CD (compact disk).

[0005] MPEG (Moving Picture Experts Group) is an international standard relating to a compression technique for video data (image signal of moving picture), and MPEG1 is the standard for compressing video data to 1.5Mbps, i.e., data of a television signal to about 1/100. Since the transmission rate of targets to which MPEG1 standard is directed is limited to about 1.5Mbps, in MPEG2 which has been standardized to meet the demand for higher image quality, video data is compressed to 2 SIMILAR 15 Mbps.

[0006] MPEG2 is the most representative international standard relating to a digital image coding method, and MPEG2 is now rapidly spread in the technical fields relating to digital TV broadcasting and digital video disks.

[0007] Furthermore, under the existing circumstances, standardization of a video data compression technique, which enables coding and signal processing in object units and realizes new functions required in the age of multimedia, is now proceeded as MPEG4 by the working group which has carried out standardization of MPEG1 and MPEG2 (ISO/IEC JTC1/SC29/WG11). MPEG4 has originally aimed at standardization of a coding method of low bit rate, but the target of standardization of MPEG4 is now extended to a more versatile coding method of higher bit rate which is adaptable to an interlace image.

[0008] Meanwhile, MPEG2 is a standard adapted to a versatile coding method, and it can be employed under different conditions according to various uses. The condition to employ MPEG2 depends on factors relating to the image quality, such as the number of pixels on a display, the bit rate of a coded image signal (bit stream), etc.

[0009] However, in each image processing equipment, since the performance of hardware is restricted by cost, a bit stream which is available as an input image signal is restricted to a bit stream which has been coded under predetermined conditions.

[0010] For example, a decoder of an ordinary definition television cannot decode a bit stream of a HDTV (High Definition Television) which is adapted to an image of high pixel rate.

[0011] On the other hand, supposing a recorder capable of recording a bit stream which has been obtained by coding an image signal with a bit rate of 6Mbps, for a length equivalent to two hours of video, this recorder can achieve longer-hour recording of the bit stream for a length equivalent to four hours of video by compressing the input bit stream having the bit rate of 6Mbps so that the bit stream becomes 3Mbps.

[0012] Hence, there is a demand for a transcoding technique for transforming an MPEG2 bit stream inputted to each image processing equipment, into an MPEG2 bit stream adapted to the performance of hardware or the use, in the image processing equipment. In recent years, many reports of researches on such transcoding technique have been presented (e.g, Gertjan Keesman, Robert Hellinghuizen, Fokke Hoeksema, Geert Heideman, "Transcoding of MPEG bitstreams", Signal Processing: Image Communication, Vol.8, 1996, pp.481-500).

[0013] Figure 20 is a block diagram for explaining a transcoding system 100a according to a prior art.

[0014] The transcoding system 100a comprises a decoding unit D1 and an encoding unit E1. The decoding unit D1 receives an MPEG2 bit stream Eg1 obtained by subjecting image data to a coding process based on MPEG2, and subjects the bit stream Eg1 to a decoding process, thereby generating decoded data Rg1. The encoding unit E1 subjects the decoded data Rg1 to a coding process based on MPEG2 under a condition different from that of the above-mentioned coding process, thereby generating transcoded data Eg2. The MPEG2 bit stream is obtained by coding image data, for every image space as a coding unit (block) which comprises a predetermined number of pixels. Therefore, the decoding unit D1 performs the decoding process for the bit stream, block by block, and the encoding unit E1 performs the coding process for the decoded data Rg1, block by block.

[0015] Next, the structure of the decoding unit D1 will be described in detail.

[0016] The decoding unit D1 includes a VLD (Variable Length Decoding) unit 100 for subjecting the coded MPEG2 bit stream Eg1 to VLD; an inverse quantization unit 101 for subjecting the output Vg from the VLD 100 to inverse quantization; and an IDCT (Inverse Discrete Cosine Transform) unit 102 for subjecting the output IQg from the inverse quantization unit 101 to IDCT by which frequency-domain data is transformed to space-domain data. Further, the decoding unit D1 includes an adder 103 for adding the output data ITg from the IDCT unit 102 and its prediction data Mg1; and a frame memory 104 for storing the output Rg1 from the adder 103 as the prediction data Mg1. The output Rg1 from the adder 103 is output as the decoded data.

[0017] Next, the structure of the encoding unit E1 will be described in detail.

[0018] The encoding unit E1 includes a subtracter 105 for calculating a difference Dg between the output data Rg1 from the decoding unit D1 and its prediction data Mg2; a DCT (Discrete Cosine Transform) unit 106 for subjecting the output Dg from the subtracter 105 to DCT by which space-domain data is transformed to frequency-domain data; and a quantization unit 107 for subjecting the output Tg from the DCT unit 106 to quantization based on a quantization control signal Cq. Further, the encoding unit E1 includes a VLC (Variable-Length Coding) unit 112 for subjecting the output Qg from the quantization unit 107 to VLC; and a rate control unit 113 for outputting the quantization control signal Cq to the quantization unit 107 on the basis of the output Eg2 from the VLC unit 112. The output Eg2 from the VLC unit 112 is output as the transcoded data.

[0019] The rate control unit 113 calculates the target number of bits when coding the DCT output Tg corresponding to a block to be coded (target block), and outputs the obtained target number of bits as the quantization control signal Cq to the quantization unit 107.

[0020] Further, the encoding unit E1 includes an inverse quantization unit 108 for subjecting the output Qg from the quantization unit 107 to inverse quantization; and an IDCT unit 109 for subjecting the output IQg2 from the inverse quantization unit 108 to IDCT. Furthermore, the encoding unit E1 includes an adder 110 for adding the output data ITg2 from the IDCT unit 109 and its prediction data Mg2; and a frame memory 111 for storing the output Rg2 from the adder 110. The output Mg2 from the frame memory 111 is output as the prediction data.

[0021] Figure 21 is a block diagram illustrating the quantization unit 107 in more detail. The quantization unit 107 comprises a quantization step derivation unit 200 for deriving a quantization step Qs2 on receipt of the target

number of bits C_q from the rate control unit 113; and a quantizer 201 for quantizing the output T_g from the DCT unit 106 on the basis of the quantization step Q_{s2} .

[0022] Next, the operation of the transcoding system 100a will be described.

[0023] Initially, coded data E_{g1} , which has been obtained by coding an image signal, is input to the decoding unit D1.

[0024] In the VLD unit 100, the coded data E_{g1} is transformed to quantized coefficients V_g by variable-length decoding, and the quantized coefficients V_g are output to the inverse quantization unit 101. In the inverse quantization unit 101, the quantized coefficients V_g are subjected to inverse quantization based on the quantization step used in the coding process for the image signal, whereby frequency components I_{Qg} are restored. The frequency components I_{Qg} are transformed to space-domain data I_{Tg} by IDCT (Inverse Discrete Cosine Transform) in the IDCT unit 102. When the space-domain data I_{Tg} is input to the adder 103, addition of the space-domain data I_{Tg} and the prediction data M_{g1} is performed, resulting in reproduced data R_{g1} . The reproduced data R_{g1} is output as decoded data from the decoding unit D1 and, on the other hand, it is stored in the frame memory 104 as already-decoded image data (prediction data) M_{g1} .

[0025] Next, the operation of the encoding unit E1 will be described.

[0026] Initially, the reproduced data R_{g1} output from the decoding unit D1 is input to the subtracter 105. In the subtracter 105, a difference between the reproduced data R_{g1} and its prediction data M_{g2} is obtained as difference data D_g . The difference data D_g is output to the DCT unit 106. In the DCT unit 106, the difference data D_g is transformed to DCT coefficients (frequency components) T_g by DCT (Discrete Cosine Transform), and the DCT coefficients are output to the quantization unit 107.

[0027] In the quantization unit 107, the DCT coefficients T_g from the DCT unit 106 are quantized on the basis of the quantization control signal C_q from the rate control unit 113. To be specific, in the quantization step derivation unit 200 of the quantization unit 107, a quantization step different from the quantization step in the inverse quantization process in the decoding unit is derived on the basis of the quantization control signal C_q . In the quantizer 201, the DCT coefficients T_g are quantized on the basis of the derived quantization step.

[0028] The quantized values Q_g obtained by this quantization are output to the VLC unit 112 and to the inverse quantization unit 108. In the VLC unit 112, the quantized values Q_g are transformed to variable-length codes by variable-length coding, and the variable-length codes are output as transcoded data E_{g2} . In the rate control unit 113, the quantization control signal C_q is generated on the basis of the output E_{g2} from the VLC unit 112 to be output to the quantization unit 107.

[0029] On the other hand, in the inverse quantization unit 108, the quantized values Q_g from the quantization unit 107 are subjected to inverse quantization to generate DCT coefficients I_{Qg2} , and the DCT coefficients I_{Qg2} are output to the IDCT unit 109. In the IDCT unit 109, the DCT coefficients I_{Qg2} are transformed to space-domain data I_{Tg2} by IDCT (Inverse Discrete Cosine Transform), and the data I_{Tg2} is output to the adder 110. In the adder 110, addition of the output data I_{Tg2} from the IDCT unit 109 and the prediction data M_{g2} is performed, thereby generating reproduced data R_{g2} . The reproduced data R_{g2} is stored in the frame memory 111 as the prediction data M_{g2} .

[0030] In the transcoding system 100a shown in figure 20, both of the input coded data (bit stream) and the coded data output from this system are based on the same coding method (MPEG2 coding). However, the transcoding system 100a may transform coded data based on H261 standard, H263 standard, MPEG1 standard or MPEG2 standard, into coded data based on MPEG4 standard. Alternatively, the transcoding system 100a may transform coded data based on MPEG4 standard into coded data based on H263 standard.

[0031] In the above-described transcoding systems, however, it is difficult to reduce a quantization error included in the transcoded stream.

[0032] To be specific, since the coded data E_{g1} supplied to the transcoding system 100a has been obtained by subjecting image data to a coding process including a quantization process, the coded data E_{g1} contains a quantization error. Therefore, the transcoded data E_{g2} which has been obtained by subjecting the coded data E_{g1} to a decoding process and a transcoding process also contains the quantization error of the coded data E_{g1} . What is worse, depending on the condition of quantization in the transcoding process, the quantization error included in the transcoded data E_{g2} becomes significantly larger than the quantization error included in the coded data E_{g1} .

[0033] Moreover, in the transcoding system 100a, it is difficult to set the quantization step in the transcoding process so as to minimize the coding error. Hereinafter, this problem will be described in more detail.

[0034] Figure 22 is a diagram for explaining the relationship between the bit rate at a coded stream and a coding error included in the coded stream. In figure 22, the relationship between them based on the rate-error theory is indicated by a graph C on a two-dimensional coordinate plane, wherein the abscissa corresponds to the bit rate and the ordinate corresponds to the coding error.

[0035] Generally, the relationship based on the rate-error theory is realized between the bit rate and the coding error, and the lower limit of the coding error is determined according to the bit rate. In other words, the coding error can be reduced to a smaller value when the bit rate is high, but the coding error cannot be reduced so much when the bit rate is low.

[0036] Therefore, in the direct coding process, i.e., in the process of coding an image signal which has not been coded yet, an optimum quantization step is decided as follows.

[0037] Initially, a relational expression (exponential function) indicating the relationship between the bit rate and the coding error, corresponding to an image to be coded, is obtained on the basis of two pairs of bit rate and coding error which are obtained by subjecting an image signal to a coding process including a quantization process using two quantization steps. The lower limit of the coding error corresponding to the bit rate of the coded stream is obtained from this relational expression.

[0038] Next, based on this relational expression, a quantization step is determined for each frame so that the coding error of each frame is minimized, within a range where the total number of bits in each frame does not exceed the target number of bits per frame. That is, a quantization step is determined so that the actual coding error is closest to the lower limit of the coding error corresponding to the allowable maximum bit rate.

[0039] However, since this method of deriving an optimum quantization step is based on the relational expression (exponential function) indicating the relationship between the bit rate and the coding error, it cannot be used in the transcoding process which cannot derive this relational expression.

[0040] That is, in the stream obtained by the transcoding process, the coding error is the sum of the coding error included in the input stream and the coding error which occurs during the transcoding process. In this case, since the coding error included in the input stream is unknown, it is impossible to obtain a relational expression (exponential function) indicating the relationship between the bit rate and the coding error.

[0041] Further, in the quantization step derivation method, since a quantization step is determined frame by frame, the coding error cannot be efficiently reduced.

[0042] Moreover, in the quantization step derivation method, a quantization step is determined so as to minimize the coding error of the target frame to be coded, and this method is not adapted to inter-frame predictive coding based on MPEG. Hereinafter, this problem will be described briefly.

[0043] Figure 23 is a schematic diagram for explaining inter-frame predictive coding based on MPEG. Figure 24 illustrates typical image data of video to be subjected to MPEG coding, including an I frame F(1), P frames F(3) and F(5), and B frames F(2) and F(4).

[0044] As for the I frame F(1), image data of this frame is subjected to intra-frame coding without referring to image data of another frame. As for each of the P frames F(3) and F(5), image data of this frame is subjected to inter-frame predictive coding with reference to image data of an already-coded frame which is previous to this P frame in display order. As for each of the B frames F(2) and F(4), image data of this frame is subjected to inter-frame predictive coding with reference to image data of two already-coded frames which are previous and subsequent to this frame in display order. Further, display times T1 SIMILAR T5 (T1

[0117] Other constituents of the transcoding system according to this second embodiment are identical to those of the transcoding system 10 according to the first embodiment.

[0118] Figure 5 is a block diagram illustrating the quantization step derivation unit 252 in more detail.

[0119] The quantization step derivation unit 252 includes a threshold derivation unit 262 which derives a threshold Q_{th} ($=mx Q_{s1}$) on the basis of the first quantization step Q_{s1} ; a comparator 263 which compares the threshold Q_{th} with the candidate quantization step Q_{sb} generated in the candidate quantization step derivation unit 250, and outputs a comparison output CP2 indicating the result of the comparison; and a switch 264 which selects either the first quantization step Q_{s1} or the candidate quantization step Q_{sb} according to the output CP2 from the

comparator 263, and outputs it as a selected quantization step Q_{se} . When the result of comparison indicates that candidate quantization step Q_{sb} is smaller than the threshold Q_{th} , the switch 264 selects the first quantization step Q_{s1} to be output as a selected quantization step Q_{se} . When the candidate quantization step Q_{sb} is equal to or larger than the threshold Q_{th} , the candidate quantization step Q_{sb} is output as a selected quantization step Q_{se} .

[0120] Further, the quantization step derivation unit 252 includes a constant multiplier 265 which multiplies the first quantization step Q_{s1} by a constant n and outputs a constant multiple Q_{mu} ($=n \times Q_{s1}$); a comparator 266 which compares the constant multiple Q_{mu} with the candidate quantization step Q_{sb} supplied from the candidate quantization step derivation unit 250, and outputs a comparison output $CP3$ which indicates the result of comparison; and a switch 267 which selects either the selected quantization step Q_{se} from the switch 264 or the constant multiple Q_{mu} from the constant multiplier 265 on the basis of the output $CP3$ from the comparator 266, and outputs it as a second quantization step Q_{s2} . When the result $CP3$ from the comparator 266 indicates that the candidate quantization step Q_{sb} is smaller than the constant multiple Q_{mu} , the switch 267 outputs the constant multiple Q_{mu} as a second quantization step Q_{s2} . When the candidate quantization step Q_{sb} is equal to or larger than the constant multiple Q_{mu} , the switch 267 outputs the quantization step Q_{se} from the switch 264 as a second quantization step Q_{s2} .

[0121] The constant n used by the constant multiplier 265 is larger than the constant m used by the threshold derivation unit 262, and the m is variable according to the target bit rate, the frame rate, the quantization method, etc.

[0122] Figure 6 shows, with a graph D, the relationship between the second quantization step Q_{s2} obtained by the quantization step derivation unit 252 and the candidate quantization step Q_{sb} output from the candidate quantization step derivation unit 250. In this second embodiment, m and n are 1.5 and 2, respectively.

[0123] As seen from the graph D, when the candidate quantization step Q_{sb} is smaller than the threshold Q_{th} , the first quantization step Q_{s1} is output as the second quantization step Q_{s2} from the quantization step derivation unit 252. When the candidate quantization step Q_{sb} is equal to or larger than the threshold Q_{th} ($=1.5 \times Q_{s1}$) and smaller than the constant multiple Q_{mu} ($=2 \times Q_{s1}$), a value twice as large as the first quantization step Q_{s1} ($2 \times Q_{s1}$) is selected as the second quantization step Q_{s2} . When the candidate quantization step Q_{sb} is equal to or larger than the constant multiple Q_{mu} ($=2 \times Q_{s1}$), the candidate quantization step Q_{sb} is selected as the second quantization step Q_{s2} .

[0124] Next, the operation of the transcoding system will be described.

[0125] In this second embodiment, the fundamental operation of the transcoding system is identical to that of the transcoding system 10 according to the first embodiment, except the operation of the quantization step derivation unit 252 included in the quantization unit 152. Therefore, only the operation of the quantization step derivation unit 252 will be described hereinafter.

[0126] In the transcoding system of this second embodiment, when the reproduced data R_g supplied from the decoding unit $Da1$ is subjected to a coding process including a quantization process by the encoding unit $Ea1$, in the quantization unit 152, the candidate quantization step derivation unit 250 generates a candidate quantization step Q_{sb} . Then, in the quantization step derivation unit 252, one of the first quantization step Q_{s1} , the constant multiple Q_{mu} , and the candidate quantization step Q_{sb} is selected as the second quantization step, on the basis of the threshold Q_{th} and the constant multiple Q_{mu} which have been obtained from the first quantization step Q_{s1} supplied from the inverse quantization unit 101a of the decoding unit $Da1$. In the quantizer 201, frequency-domain data T_g is subjected to quantization based on the second quantization step Q_{s2} .

[0127] When the first quantization step Q_{s1} is supplied from the decoding unit $Da1$ to the quantization step derivation unit 252, the threshold derivation unit 262 derives a predetermined threshold Q_{th} by multiplying the first quantization step Q_{s1} with m , and outputs this threshold Q_{th} to the comparator 263. In the comparator 263, the candidate quantization step Q_{sb} supplied from the candidate quantization step derivation unit 250 is compared with the threshold Q_{th} supplied from the threshold derivation unit 262, and a comparison output $CP2$ indicating the result of comparison is output to the switch 264. In the switch 264, either the first quantization step Q_{s1} or the candidate quantization step Q_{sb} is selected on the basis of the comparison output $CP2$, and the selected step is output as a selected quantization step Q_{se} to the switch 267.

[0128] At this time, in the constant multiplier 265, a constant multiple Q_{mu} is generated by multiplying the first quantization step Q_{s1} supplied from the decoding unit $Da1$, with n , and this constant multiple Q_{mu} is output to the switch 267 and to the comparator 266. In the comparator 266, the candidate quantization step Q_{sb} supplied from the candidate quantization step derivation unit 250 is compared with the constant multiple Q_{mu} supplied from the

constant multiplier 265, and a comparison output CP3 indicating the result of comparison is output to the switch 267. In the switch 267, either the constant multiple Qmu or the selected quantization step Qse is selected to be output as the second quantization step Qs2.

[0129] As described above, the transcoding system according to the second embodiment is provided with the candidate quantization step derivation unit 250 which derives a candidate quantization step Qse on the basis of the relationship between the bit rate of the transcoded data and the quantization distortion included in the (second quantization step) for the transcoding process, on the basis of the candidate quantization step Qsb and the first quantization step Qs1 which is used in the inverse quantization process. When the candidate quantization step Qsb has a value within an optimum range which is determined according to the relationship in relative sizes among the candidate quantization step Qsb, the first quantization step Qs1, and the constant multiple Qmu, the candidate quantization step Qsb is output as the second quantization step Qs2. When the candidate quantization step Qsb has a value outside the range, the first quantization step Qs1 or its constant-multiple quantization step Qmu is output. Therefore, the transcoding process for the coded data Eg1 can be performed while effectively suppressing the quantization error, without increasing the number of bits.

[0130] In this second embodiment, when the candidate quantization step Qsb is smaller than the constant multiple Qmu (nx first quantization step Qs1), the second quantization step Qs2 is rounded to the first quantization step Qs1 or to the constant multiple Qmu, on the basis of the threshold Qth (mxQs1). However, the threshold Qth may be varied.

[0131] For example, the threshold Qth may be varied so that the second quantization step Qs2 frequently changes between the first quantization step Qs1 and the constant multiple Qmu. In this case, highly-responsive rate control to bring the coding bit rate close to a target bit rate, is achieved.

[0132] More specifically, the threshold Qth is varied as follows, and a quantization step Qs2 is decided according to a new threshold Qth' obtained.

[0133] Initially, the average of the candidate quantization steps Qsb is obtained at a target average quantization step Qt, and the average of the second quantization steps Qs2 is obtained as a practical average quantization step Qave.

[0134] When the practical average quantization step Qave is larger than the target average quantization step Qt, in other words, when the candidate quantization steps Qsb are relatively small values on average, $Qth' = Qth/2$ is used as a new threshold. However, when Qth' is smaller than Qs1, $Qth' = Qs1$.

[0135] On the other hand, when the practical average quantization step Qave is smaller than the target average quantization step Qt, in other words, when the candidate quantization steps Qsb are relatively large values on average, $Qth' = Qth + Qth/2$ is used as a new threshold. However, when Qth' is larger than Qmu, $Qth' = Qmu$.

[Embodiment 3]

[0136] Figure 8 is a block diagram for explaining a transcoding system 30 according to a third embodiment of the present invention.

[0137] The transcoding system 30 according to this third embodiment has a quantization unit 153 which derives quantization steps adapted to intra-frame coding and inter-frame coding, respectively, and performs quantization with these quantization steps, instead of the quantization unit 151 according to the first embodiment. As the coding process is switched between intra-frame coding and inter-frame coding in units of blocks or frames, the quantization process is also switched between that adapted to the intra-frame coding (intra-frame quantization) and that adapted to the inter-frame coding (inter-frame quantization).

[0138] Figure 9 is a block diagram illustrating the structure of the quantization unit 153 in detail.

[0139] The quantization unit 153 includes an intra-frame average quantization step derivation unit 270 and an inter-frame average quantization step derivation unit 271. The intra-frame average quantization step derivation unit 270 calculates a value Q intra (first intra-frame average quantization step Qs11) by averaging the quantization steps corresponding to the respective macroblocks in the intra-frame quantization process, for each frame, on the basis of the first quantization step Qs1 which has been used for inverse quantization in the decoding unit Da1. The inter-frame average quantization step derivation unit 271 calculates a value Q inter (first inter-frame average

quantization step QsP1) by averaging the quantization steps corresponding to the respective macroblocks in the inter-frame quantization process, for each frame, on the basis of the first quantization step Qs1.

[0140] Further, the quantization unit 153 includes an intra-frame average quantization step derivation unit 272a and an inter-frame average quantization step derivation unit 272b. The intra-frame average quantization step derivation unit 272a calculates a value Q_{intra} (second intra-frame average quantization step Qs1) by averaging the quantization steps corresponding to the respective macroblocks in the intra-frame quantization process, for each frame, on the basis of the second quantization step Qs2 which has been used for quantization of frames up to a previous frame which is immediately before the target frame to be coded. The inter-frame average quantization step derivation unit 272b calculates a value Q_{inter} (second inter-frame average quantization step QsP2) by averaging the quantization steps corresponding to the respective macroblocks in the inter-frame quantization process, for each frame, on the basis of the second quantization step Qs2.

[0141] Furthermore, the quantization unit 153 includes a quantization step derivation unit 273 and a quantizer 201. The quantization step derivation unit 273 derives a quantization step Qs2 from the target number of bits which is input as a quantization control signal C_q , with reference to the first and second intra-frame average quantization steps Qs1 and Qs2 and the first and second inter-frame average quantization steps QsP1 and QsP2. The quantizer 201 quantizes the output T_g from the DCT unit 106, on the basis of the second quantization step Qs2.

[0142] Figure 10 is a block diagram illustrating the quantization step derivation unit 273 in detail.

[0143] The quantization step derivation unit 273 includes a decision unit 710 for deciding the target number of bits per frame, a decision unit 711 for deciding the target number of bits per macroblock, and a quantization step decision unit 712. More specifically, the decision unit 710 calculates the target number of bits fC_g for a target frame to be subjected to re-quantization, from the target number of bits corresponding to a target macroblock to be processed, which is indicated by the quantization control signal C_q , on the basis of the first intra-frame average quantization step Qs1 and the first inter-frame average quantization step QsP1. The decision unit 711 generates the number of available bits mC_g for the target macroblock, on the basis of the target number of bits fC_g for the target frame and the quantization control signal C_q supplied from the rate control unit 113. The quantization step decision unit 712 decides a quantization step Qs2 for the target macroblock, on the basis of the number of bits mC_g , the second intra-frame average quantization step Qs12, the second inter-frame average quantization step QsP2, and the quantization control signal C_q supplied from the rate control unit 113.

[0144] Now it is assumed that the value of the first intra-frame average quantization step Qs1 is Q_{intra} , the value of the first inter-frame average quantization step QsP1 is Q_{inter} , the number of coded bits per intra-frame coded frame is N_{intra} , the number of coded bits per inter-frame coded frame is N_{inter} , and the ratio of the intra-frame re-quantization step to the inter-frame re-quantization step is $\alpha \times Q_{intra} : Q_{inter}$ so that the ratio of the re-quantization errors in the intra-frame coding process and the inter-frame coding process is corrected. Since the quantization step is in inverse proportion to the number of coded bits, the ratio of the number of bits per intra-frame coded frame to the number of bits per inter-frame coded frame after the re-quantization becomes $N_{intra} / \alpha : N_{inter}$. The value of α satisfies $0 < \alpha \leq Q_b / Q_a$ and a local decoding process, with reference to the reference image data V_c stored in the simulation memory C or the reference image data V_{refc} stored in the main memory U3d. The quantization step Q_c should not be smaller than the quantization step Q_{in} used in the inverse quantization process. Then, the simulation encoder C outputs locally decoded image data V_{strc} , the quantization step Q_c corresponding to each coding unit, the number of simulation-coded bits R_c , and the simulating coding error D_c .

[0236] At this time, the locally decoded image data V_{strc} is stored in the simulation memory C, as image data of a frame which has already been processed. The image data stored in the simulation memory C is used as the above-described reference image data V_c when performing simulation coding on image data of an unprocessed frame.

[0237] In the quantization step derivation unit U75, an optimum quantization step Q_d corresponding to each block (coding unit) is derived so that the transcoding error increasing rate corresponding to each block does not exceed the average transcoding error increasing rate (target transcoding error increasing rate) λ corresponding to the target frame, on the basis of the quantization steps Q_a , Q_b and Q_c , the numbers of simulation-coded bits R_a , R_b and R_c , and the simulation coding errors D_a , D_b and D_c , which are supplied from the simulation encoders A, B, and C, respectively.

[0238] In the main encoder U2d, as in the fourth embodiment, the decoded image data V_{dec} is subjected to a transcoding process which includes a quantization process using the optimum quantization step Q_d and a local decoding process, with reference to the reference image data V_{refd} stored in the main memory U3d. Thereby, a

transcoded stream Vout and locally decoded image data Vstrd are output from the main encoder U2d.

[0239] In the rate distortion calculator U5, on the basis of the transcoded stream Vout corresponding to each frame, a relatively large value is output as a transcoding error increasing rate λ when the average bit rate of the frame being coded is likely to be larger than the target frame bit rate, and a relatively small value is output as a transcoding error increasing rate λ when the average bit rate of the frame being coded is likely to be smaller than the target frame bit rate.

[0240] Hereinafter, the operation of the quantization step derivation unit U75 will be described in more detail.

[0241] Initially, the first number-of-bits subtracter U8b performs subtraction to obtain a variation in the number of simulation-coded bits DELTA Rab, the first error subtracter U9b performs subtraction to obtain a variation in the simulation coding error DELTA Dab, and the first divider U10b performs arithmetic to obtain a transcoding error increasing rate λ_1 . Further, the second number-of-bits subtracter U8c performs subtraction to obtain a variation in the number of simulation-coded bits DELTA Rbc, the second error subtracter U9c performs subtraction to obtain a variation in the simulation coding error DELTA Dbc, and the second divider U10c performs arithmetic to obtain a transcoding error increasing rate λ_2 .

[0242] The processes in the first number-of-bits subtracter U8b, the first error subtracter U9b, and the first divider U10b are identical to those already described for the fourth embodiment, and the processes in the second number-of-bit subtracter U8c, the second error subtracter U9c, and the second divider U10c are identical to those performed by the subtracter U8b, the subtracter U9b, and the divider U10b.

[0243] To be specific, in the second number-of-bits subtracter U8c, the number of third-simulation-coded bits Rc is subtracted from the number of second-simulation-coded bits Rb to obtain a difference DELTA Rbc of these numbers (a variation in the number of simulation-coded bits). In the second error subtracter U9c, the simulation coding error Db supplied from the simulation encoder B is subtracted from the simulation coding error Dc supplied from the simulation encoder C to obtain a difference DELTA Dbc of these errors (a variation in the simulation coding error). Further, in the second divider U10c, the variation in the simulation coding error DELTA Dbc is divided by the variation in the number of simulation-coded bits DELTA Rbc to derive the second transcoding error increasing rate λ_2 .

[0244] Further, in the first comparator U11b, the first transcoding error increasing rate λ_1 supplied from the divider U10b is compared with the transcoding error increasing rate λ of the current transcoding process, and a first control signal Qseb according to the result of comparison is output. In the second comparator U11c, the second transcoding error increasing rate λ_2 supplied from the divider U10c is compared with the transcoding error increasing rate λ in the current transcoding process, and a second switch control signal Qsec according to the result of comparison is output.

[0245] Then, in the selector switch U50, one of the quantization steps Qa, Qb, and Qc supplied from the simulation encoders A, B, and C is selected on the basis of the first and second switch control signals Qseb and Qsec, and the selected quantization step is output as an optimum quantization step Qd.

[0246] To be specific, when the transcoding error increasing rate λ is equal to or smaller than the transcoding error increasing rate λ_1 , the switch U50 selects the quantization step Qa as an optimum quantization step Qd, according to the switch control signal Qseb. When the transcoding error increasing rate λ is larger than the transcoding error increasing rate λ_1 and equal to or smaller than the transcoding error increasing rate λ_2 , the switch U50 selects the quantization step Qb as an optimum quantization step Qd, according to the switch control signals Qseb and Qsec. When the transcoding error increasing rate λ is larger than the transcoding error increasing rate λ_2 , the switch U50 selects the quantization step Qc as an optimum quantization step Qd, according to the switch control signal Qsec.

[0247] As described above, the transcoding system of this fifth embodiment is provided with the rate distortion calculator U5 which compares the bit rate of the transcoded stream Vout (the current bit rate) from the main encoder U2d with the target bit rate Rate supplied from the outside, and calculates an average transcoding error increasing rate λ which becomes an index of image quality of the target frame, according to the result of comparison. When the first and second transcoding error increasing rates λ_1 and λ_2 ($\lambda_1 < \lambda_2$) corresponding to each coding unit (block), which are obtained from the results of the coding processes in the simulation encoders A, B, and C having different quantization steps Qa, Qb, and Qc (Qa

[0248] In this fifth embodiment, the transcoding system 50 includes three simulation encoders, and the first and second transcoding error increasing rates λ_1 and λ_2 are compared with the average transcoding error increasing rate λ corresponding to one frame to decide the optimum quantization step Qd for each block. However, the number of simulation encoders is not restricted to three, and it may be two as in the fourth

embodiment, or more than three.

[0249] For example, it is assumed that the transcoding system 50 includes two simulation encoders A and B. In this case, when the first transcoding error increasing rate λ_1 corresponding to each block, which is obtained from the results of the coding processes in the simulation encoders A and B having different quantization steps Q_a and Q_b (Q_a

[Embodiment 6]

[0250] Figure 17 is a block diagram for explaining a transcoding system according to a sixth embodiment of the present invention, illustrating a quantization step derivation unit included in this transcoding system.

[0251] The transcoding system of this sixth embodiment has a quantization step derivation unit U76, instead of the quantization step derivation unit U75 according to the fifth embodiment. The quantization step derivation unit U76 obtains the relational expression between the transcoding error increasing rate λ and the quantization step Q on the basis of the quantization steps Q_a , Q_b , and Q_c , the numbers of simulation-coded bits R_a , R_b , and R_c , and the simulation coding errors D_a , D_b , and D_c , which are obtained as the results of simulation coding processes in the respective simulation encoders, and then obtains the optimum quantization step Q_d for each coding unit on the basis of the relational expression and the target coding error increasing rate λ supplied from the rate distortion calculator U5. Other constituents of the transcoding system according to this sixth embodiment are identical to those of the transcoding system according to the fifth embodiment.

[0252] Hereinafter, the quantization step derivation unit U76 will be described in more detail by using figure 17.

[0253] The quantization step derivation unit U76 includes an RD differential calculator U12 and a quantization step calculator U31, instead of the first and second comparators U11b and U11c and the switch U50 included in the quantization step derivation unit U75 of the fifth embodiment. The RD differential calculator U12 derives an RD differential function f indicating the relationship between the target transcoding error increasing rate λ and the bit rate R . By using the RD differential function f , the quantization step calculator U31 calculates an optimum quantization step corresponding to the transcoding error increasing rate λ , for each coding unit, from the relationship between the quantization step Q and the number of transcoded bits R (i.e., the number of bits corresponding to each coding unit which is obtained by coding the decoded stream V_{dec}). The bit rate is equivalent to the number of bits corresponding to each coding unit.

[0254] Hereinafter, the RD differential calculator U12 and the quantization step calculator U31 will be described in more detail.

[0255] Generally, a function represented by the following formula (6) (rate-error function) is realized between the number of coded bits R in each block (coding unit) and the coding error D of each block.

"(6)" $D=g(R)$

[0256] So, in the transcoding process, the coding error D including in the transcoded stream is represented by

"(7)" $\Delta D + D_{in} = g(R)$

where ΔD is the transcoding error (coding error increased in the transcoding process), and D_{in} is the coding error of the input stream V_{in} .

[0257] Accordingly, the transcoding error increasing rate λ is represented by

"(8)" $\lambda = \frac{\text{DIFFERENTIAL } D}{\text{DIFFERENTIAL } R} = \frac{\text{DIFFERENTIAL } \Delta D}{\text{DIFFERENTIAL } R} = \frac{\text{DIFFERENTIAL } g(R)}{\text{DIFFERENTIAL } R}$

[0258] It is known that the function $g(R)$ can be approximated as follows.

"(9)" $g(R) = A \cdot R$

wherein A and B are constants.

[0259] Accordingly, from formulae (8) and (9), the transcoding error increasing rate λ is represented as follows.

"(10)" $\lambda = A \cdot R$

[0260] Assuming that the transcoding error increasing rate λ_1 is a transcoding error increasing rate λ

when $R=R_b$ and the transcoding error increasing rate λ_2 is a transcoding error increasing rate λ when $R=R_c$, the constants A and B are obtained from formula (10). As the result, an RD differential function f represented as follows is derived.

"(11)" $R = f(\lambda)$

[0261] The RD differential calculator U12 performs an arithmetic for deriving the function f represented by formula (11), on the basis of the bit rates R_b and R_c of the transcoded streams supplied from the simulation encoders B and C, and the transcoding error increasing rates λ_1 and λ_2 supplied from the dividers U10b and U10c.

[0262] On the other hand, the quantization step Q and the bit rate R have the relationship represented by

"(12)" $R = \alpha \cdot Q$

wherein α and β are constants, and α and β are obtained by assigning the bit rates R_b and R_c and the quantization steps Q_b and Q_c . As the result, a function h represented by the following formula (13) is derived.

"(13)" $R = h(Q)$

[0263] Accordingly, from formulae (11) and (13), a function s indicating the relationship between the transcoding error increasing rate λ and the quantization step Q is obtained as follows.

"(14)" $Q = s(\lambda)$

[0264] In other words, the quantization step corresponding to the transcoding error increasing rate λ can be derived as the optimum quantization step Q_d , by using formula (14).

[0265] The quantization step calculator U31 performs an arithmetic to derive the function h represented by formula (13) on the basis of the number of simulation-coded bits R_b supplied from the simulation encoder B, the quantization step Q_b used in the second simulation coding process, the number of simulation-coded bits R_c supplied from the simulation encoder C, and the quantization step Q_c used in the third simulation coding process. Further, the calculator U31 derives the function s from the function h and the function f which is obtained by the RD differential calculator U12 and, furthermore, it derives, from this function s, a quantization step corresponding to the target transcoding error increasing rate λ which is obtained by the rate distortion calculator U5, as an optimum quantization step Q_d .

[0266] Next, the operation of the transcoding system according to this sixth embodiment will be described.

[0267] The operation of the transcoding system according to this sixth embodiment is identical to that of the transcoding system 50 according to the fifth embodiment, except the operation of the quantization step derivation unit U76.

[0268] So, only the operation of the quantization step derivation unit U76 will be described hereinafter.

[0269] In this sixth embodiment, initially, the first number-of-bits subtracter U8b performs subtraction to obtain a variation in the number of simulation-coded bits ΔR_b , the first error subtracter U9b performs subtraction to obtain a variation in the simulation coding error ΔD_b , and the first divider U10b performs arithmetic to obtain the transcoding error increasing rate λ_1 . Further, the second number-of-bits subtracter U8c performs subtraction to obtain a variation in the number of simulation-coded bits ΔR_c , the second error subtracter U9c performs subtraction to obtain a variation in the simulation coding error ΔD_c , and the second divider U10c performs arithmetic to obtain a transcoding error increasing rate λ_2 .

[0270] In the RD differential calculator U12, the function f ($R=f(\lambda)$) represented by formula (11) is derived on the basis of the numbers of simulation-coded bits R_b and R_c obtained in the simulation encoders B and C, and the transcoding error increasing rates λ_1 and λ_2 supplied from the first and second dividers U10b and U10c.

[0271] Further, in the quantization step calculator U31, the function h ($R=h(Q)$) represented by formula (13) is derived on the basis of the number of simulation-coded bits R_b supplied from the simulation encoder B, the quantization step Q_b used in the second simulation coding process, the number of simulation-coded bits R_c supplied from the simulation encoder C, and the quantization step Q_c used in the third simulation coding process. Further, the function s ($Q=s(\lambda)$) represented by formula (14) is obtained from the function h and the function f which is obtained by the RD differential calculator U12. Further, by using this function s, a quantization step corresponding to the target transcoding error increasing rate λ which is obtained by the rate distortion

calculator U5, is obtained as an optimum quantization step Qd.

[0272] As described above, in the transcoding system according to this sixth embodiment, the quantization step derivation unit U76 is provided with the RD differential calculator U12 which derives the function $f(R=f(\lambda))$ indicating the relationship between the transcoding error increasing rate λ and the bit rate on the basis of the result of simulation coding; and the quantization step calculator U31 which obtains the function $s(Q=s(\lambda))$ indicating the relationship between the transcoding error increasing rate λ and the quantization step, on the basis of the function f and the result of simulation coding, and then derives a quantization step corresponding to the target transcoding error increasing rate λ obtained in the rate distortion calculator U5, as an optimum quantization step Qd for each coding unit, by using the function s . Therefore, the optimum quantization step Qd corresponding to each coding unit can be set more minutely.

[0273] In this sixth embodiment, the RD differential function f is derived on the basis of a difference between the simulation coding errors Db and Da, a difference between the numbers of simulation-coded bits Ra and Rb, a difference between the simulation coding errors Db and Dc, and a difference between the numbers of simulation-coded bits Rb and Rc. However, a difference between the simulation coding errors Dc and Da may be used as the above-mentioned difference between the simulation coding errors. Further, a difference between the numbers of simulation-coded bits Ra and Rc may be used as the difference between the numbers of simulation-coded bits for each coding unit (block).

[Embodiment 7]

[0274] Figure 18 is a block diagram for explaining a transcoding system according to a seventh embodiment of the present invention, illustrating a quantization step derivation unit included in the transcoding system.

[0275] The transcoding system of this seventh embodiment includes a quantization step derivation unit U77 instead of the quantization step derivation unit U76 according to the sixth embodiment. The quantization step derivation unit U77 selects either a quantization step Qf which is output from the quantization step calculator U31 or the smallest quantization step Qa among the quantization steps Qa, Qb, and Qc, according to the transcoding error increasing rate λ_1 , and outputs the selected quantization step as an optimum quantization step Qd.

[0276] Hereinafter, the quantization step derivation unit U77 will be described in more detail by using figure 18.

[0277] The quantization step derivation unit U77 includes a comparator U11 and a selector switch U70, in addition to the constituents of the quantization step derivation unit U76 according to the sixth embodiment. The comparator U11 compares the first transcoding error increasing rate λ_1 supplied from the first divider U10b with the target transcoding error increasing rate λ supplied from the rate distortion calculator U5, and outputs a switch control signal Qse. The selector switch U70 selects either the quantization step Qf output from the quantization step calculator U31 or the smallest quantization step Qa, according to the switch control signal Qse, and outputs the selected quantization step and an optimum quantization step Qd.

[0278] Hereinafter, the comparator U11 will be described more specifically.

[0279] Generally, in the transcoding system, when a difference between the size of the quantization step Q_{in} used in the coding process for the input stream V_{in} and the size of the quantization step Qd used in the transcoding process is large, i.e., when the transcoding error increasing rate λ increases monotonously as the quantization step Qd increases. On the other hand, when the difference between the size of the quantization step Q_{in} used in the coding process for the input stream V_{in} and the size of the quantization step Qd used in the transcoding process is small, i.e., when the transcoding error increasing rate λ is small, the transcoding error increasing rate λ does not necessarily increase even when the quantization step Qd increases, and it may decrease according to the circumstances. This has already been described for the second embodiment of the invention by using figure 7, and is described in more detail in "Study on Transcoding Error in MPEG2 Transcoding", IE99-32, The Institute of Electronics, Information and Communication Engineers.

[0280] That is, in figure 7, the quantization error in the transcoded data is large when its bit rate is high, i.e., when a difference between the quantization step value Q_{Pi} used in the first quantization process (quantization process in the coding process) and the quantization step value Q_{Pr} used in the second quantization process (quantization process in the transcoding process) is small. On the other hand, when the quantization step value Q_{Pr} in the second quantization process is equal to or larger than 2Q₂ (Q_{Pi}=Q_P) and the bit rate of the transcoded data is low, there is little difference between the quantization error in the direct coding process and the quantization error in the transcoding process. The increase or decrease in the quantization error in the transcoded data corresponds

to the increase or decrease in the transcoding error increasing rate.

[0281] So, the comparator U11 controls the selector switch U70 so that the switch U70 selects the smallest quantization step Qa amongst the quantization steps Qa, Qb, and Qc (Qa

[0282] In other words, this seventh embodiment is obtained by combining the transcoding system of the sixth embodiment and the transcoding system of the second embodiment. To be specific, the comparator U11 and the selector switch U70 included in the quantization step derivation unit U77 of this seventh embodiment correspond to the quantization step derivation unit 252 included in the quantization unit 152 of the second embodiment, and part of the derivation unit U77 other than the comparator U11 and the selector switch U70 corresponds to the candidate quantization step derivation unit 250.

[0283] In the quantization step derivation unit U77 of this seventh embodiment, the transcoding error increasing rate λ_1 obtained in the simulation coding process is compared with the target transcoding error increasing rate λ of the target frame. When $\lambda_1 < \lambda$, and either the first quantization step Qs1 or the constant multiple Qmu is selected as a quantization step when $\lambda_1 \geq \lambda$

[0284] Next, the operation of the transcoding system will be described.

[0285] The operation of the transcoding system of this seventh embodiment is identical to that of the transcoding system 50 of the fifth embodiment except the operation of the quantization step derivation unit U77.

[0286] Therefore, only the operation of the quantization step derivation unit U77 will be described hereinafter.

[0287] In this seventh embodiment, the subtracters U8b and U8c, the subtracters U9b and U9c, the dividers U10b and U10c, the RD differential calculator U12, and the quantization step calculator U31 perform the same arithmetic processing as that described for the sixth embodiment. Thereby, first and second transcoding error increasing rates λ_1 and λ_2 corresponding to each coding unit (target block) are output from the dividers U10b and U10c, respectively. Further, an RD differential function f is derived from the RD differential calculator U12, and a value Qf corresponding to the target coding error increasing rate λ is output as a quantization step for the target block from the quantization step calculator U31.

[0288] In the comparator U11, the first transcoding error increasing rate λ_1 corresponding to the target block is compared with the target transcoding error increasing rate λ corresponding to the target frame, and a switch control signal Qse is output to the selector switch U70 according to the result of comparison. In the selector switch U70, according to the switch control signal Qse, either the quantization step Qf from the quantization step calculator U31 or the quantization step Qa used in the first simulation coding process is selected and output as an optimum quantization step Qd.

[0289] To be specific, when the first transcoding error increasing rate λ_1 corresponding to the target block is smaller than the target transcoding error increasing rate λ corresponding to the target frame, the selector switch U70 selects the quantization step Qa as an optimum quantization step Qd according to the switch control signal Qse. On the other hand, when the first transcoding error increasing rate λ_1 is not smaller than the target transcoding error increasing rate λ , the selector switch U70 selects the quantization step Qf from the quantization step calculator U31 as an optimum quantization step Qd.

[0290] As described above, in the transcoding system of this seventh embodiment, the quantization step derivation unit U77 includes, in addition to the constituents of the quantization step derivation unit U76 of the sixth embodiment, the comparator U11 which compares the transcoding error increasing rate λ_1 from the divider U10b with the target transcoding error increasing rate λ from the rate distortion calculator, and outputs a switch control signal Qse according to the result of comparison. Only when the transcoding error increasing rate λ_1 is smaller than the target transcoding error increasing rate λ , the smallest quantization step Qa in the simulation coding process is selected as a quantization step for the target block, instead of the quantization step Qf obtained by the quantization step calculator U31. Therefore, when variation in the transcoding error increasing rate with increase in the quantization step is not monotonous increase and the transcoding error increasing rate has a value within a range in which the quantization step calculator U31 cannot easily derive an optimum quantization step Qd with which the transcoding error is minimized, the smallest quantization step Qa used in the simulation coding process is always used as an optimum quantization step for the target block.

[0291] Therefore, when the target transcoding error increasing rate λ of the target frame has a value within a range in which the difference between the quantization step Q_{in} of the input stream V_{in} and the quantization step Qd in the transcoding process for the input stream V_{in} becomes small, the operation of the transcoding system is prevented from being unstable. Further, when the target transcoding error increasing rate λ of the target frame is outside the range, the quantization step Qf derived from the quantization step calculator U31 is used as the quantization step Qd, whereby the transcoding error is minimized.

[0292] In the sixth and seventh embodiments of the present invention, the RD differential function f shown in formula (11) is used as a function indicating the relationship between the number R of coded bits per coding unit of the transcoded stream and the transcoding error increasing rate λ . However, a function indicating this relationship is not restricted thereto.

[0293] For example, when another RD differential function having similar tendency and character to those of the RD differential function f can be derived from the simulation coding errors D_a , D_b and D_c and the numbers of simulation-coded bits R_a , R_b , and R_c , this RD differential function may be used as a function indicating the relationship between the number of coded bits R and the transcoding error increasing rate λ .

[0294] Further, in the fifth to seventh embodiments, the transcoding system includes the simulation encoders A , B , and C which perform simulation transcoding including quantization on only a frame to be transcoded in the main encoder $U2d$. However, the structure of the transcoding system is not restricted thereto.

[0295] For example, as described for the fourth embodiment, when the transcoding system performs inter-frame predictive coding based on MPEG, the simulation encoders A , B , and C may perform simulation coding not only on the target frame to be subjected to transcoding in the main encoder $U2d$ but also on other frames which use this target frame as a reference frame when being subjected to transcoding.

[0296] When a program for executing, by using software, a transcoding process of any of the above-described transcoding systems according to the first to seventh embodiments, is recorded in a data storage medium such as a floppy disk, the transcoding process can be easily realized in an independent computer system.

[0297] Figures 19(a)-19(c) are diagrams illustrating a data storage medium (figures 19(a) and 19(b)) which contains a program for performing the transcoding process according to any of the aforementioned embodiments by using a computer system, and the computer system (figure 19(c)).

[0298] Figure 19(a) shows a front view of a floppy disk, a cross-sectional view thereof, and a floppy disk body (storage medium body) FD . Figure 19(b) shows an example of a physical format of the floppy disk FD .

[0299] The floppy disk FD is contained in a floppy disk case F . On the surface of the floppy disk FD , a plurality of tracks Tr are formed concentrically from the outer circumference of the disk toward the inner circumference. Each track Tr is divided into 16 sectors (Se) in the angular direction. Therefore, in the floppy disk FD containing the above-mentioned program, the program is recorded in the assigned sectors (Se) on the floppy disk FD .

[0300] Figure 19(c) shows the structure for recording and playback of the program in/from the floppy disk FD . When the program is recorded in the floppy disk FD , data as the program is read from a computer system Cs and written in the floppy disk FD through a floppy disk drive FDD . When the transcoding system according to any of the aforementioned embodiments is constructed in the computer system Cs according to the program recorded in the floppy disk FD , the program is read from the floppy disk FD by using the floppy disk drive FDD and then loaded to the computer system Cs .

[0301] Although in the above description a floppy disk is employed as a data storage medium, even when an optical disk is employed, the transcoding process by software can be performed in the same manner as described for the floppy disk. Further, the data storage medium is not restricted to the floppy disk and the optical disk, other media may be employed as long as the program can be recorded therein. For example, an IC card or a ROM cassette may be employed. Also when using these data storage media, the transcoding process using software can be performed in the same manner as described for the floppy disk.

Data supplied from the esp@cenet database - 12

Claims

1. A coded data transform method including a decoding process for decoding first coded data which has been obtained by subjecting image data to a coding process including a first orthogonal transform process and a first quantization process, for each coding unit, to generate decoded data; and a transcoding process for coding the decoded data, for each coding unit, to generate second coded data,

said decoding process including:

an inverse quantization process for inversely quantizing quantized coefficients obtained from the first coded data, by using a first quantization step which has been used in the first quantization process; and

said transcoding process including:

a second orthogonal transform process for subjecting the decoded data to orthogonal transform to generate frequency-domain data; and

a second quantization process for deriving a second quantization step on the basis of the second coded data and the first quantization step, and quantizing the frequency-domain data with the second quantization step.

2. The coded data transform method of claim 1 wherein said second quantization process further includes:

a candidate derivation process for deriving a candidate quantization step on the basis of the second coded data; and

a quantization step derivation process for deriving the second quantization step on the basis of the candidate quantization step and the first quantization step.

3. The coded data transform method of Claim 2 wherein:

in said quantization step derivation process,

when the candidate quantization step has a value which is equal to or larger than the value of the first quantization step and smaller than twice the value of the first quantization step, a quantization step having the same value as that of the first quantization step or a quantization step having a value equal to or larger than twice the value of the first quantization step is derived as the second quantization step; and

when the candidate quantization step has a value outside the above-described range, the candidate quantization step is derived as the second quantization step.

4. The coded data transform method of Claim 1 wherein:

said coding process includes a first intra-frame coding process utilizing the correlation of pixel values in a frame, and a first inter-frame coding process utilizing the correlation of pixel values between frames, and said first intra-frame coding process includes a first intra-frame quantization process while said first inter-frame coding process includes a first inter-frame quantization process;

said transcoding process includes a second intra-frame coding process utilizing the correlation of pixel values in a frame, and a second inter-frame coding process utilizing the correlation of pixel values between frames, and said second intra-frame coding process includes a second intra-frame quantization process while said second inter-frame coding process includes a second inter-frame quantization process;

said decoding process includes an intra-frame decoding process adapted to the intra-frame coding process, and an inter-frame decoding process adapted to the inter-frame coding process, and said intra-frame decoding process includes an intra-frame inverse quantization process while said inter-frame decoding process includes an inter-frame inverse quantization process; and

said second quantization process includes:

an average quantization step derivation process for deriving the average of quantization steps of all coding units in the first intra-frame quantization process as a first intra-frame average quantization step, the average of quantization steps of all coding units in the second intra-frame quantization process as a second intra-frame average quantization step, the average of quantization steps of all coding units in the first inter-frame quantization process as a first inter-frame quantization step, and the average of quantization steps of all coding units in the second inter-frame quantization process as a second inter-frame quantization step; and

a quantization step derivation process for deriving the second quantization step on the basis of these average

quantization steps and the transcoded data.

5. The data transform method of Claim 4 wherein, in said second quantization step derivation process, the second quantization step is derived so that the ratio of the second intra-frame average quantization step to the first intra-frame average quantization step is smaller than the ratio of the second inter-frame average quantization step to the first inter-frame average quantization step.

6. A transcoding system comprising a decoding unit for receiving coded data which has been obtained by subjecting image data of each coding unit to a coding process including a first orthogonal transform process and a first quantization process, and decoding the input coded data for each coding unit to generate decoded data; and an encoding unit for coding the decoded data to generate transcoded data,

said decoding unit including:

an inverse quantizer for inversely quantizing quantized coefficients obtained from the input coded data, with a first quantization step which has been used in the first quantization process; and

said encoding unit including:

a frequency transform unit for subjecting the decoded data to a second orthogonal transform process to generate frequency-domain data; and

quantization means for subjecting the frequency-domain data to a second quantization process with a second quantization step which is derived on the basis of the transcoded data and the first quantization step.

7. The transcoding system of Claim 6 wherein:

said inverse quantizer performs inverse quantization corresponding to either intra-frame quantization or inter-frame quantization, according to that the coding process performed on the input coded data is either intra-frame coding or inter-frame coding; and

said quantization means comprises:

a first step derivation unit for averaging the quantization steps of all coding units in the inverse quantization process corresponding to the intra-frame quantization process, on the basis of the first quantization step supplied from the inverse quantizer, thereby deriving an intra-frame average quantization step;

a second step derivation unit for averaging the quantization steps of all coding units in the inverse quantization process corresponding to the inter-frame quantization, on the basis of the first quantization step supplied from the inverse quantizer, thereby deriving an inter-frame average quantization step; and

a quantization step derivation unit for deriving a second quantization step on the basis of the transcoded data, the intra-frame average quantization step, and the inter-frame average quantization step; and

said quantization means quantizes the frequency-domain data with the second quantization step.

8. A data storage medium containing a data transform program for making a computer perform the coded data transform method of Claim 1.

9. A transcoding method for transforming an input stream obtained by coding an image signal, into a transcoded stream having a bit rate lower than a specified bit rate, in a transcoding process, said method comprising:

a decoding process for decoding the input stream to generate a decoded stream;

a plurality of simulation coding processes having different quantization steps, for successively quantizing and coding the decoded stream for every coding unit;

a quantization step derivation process for deriving an optimum quantization step so that a difference between the bit rate of the transcoded stream and the specified bit rate is minimized, on the basis of the numbers of bits per coding unit which are obtained in the respective simulation coding processes, the increments of coding error due to the respective simulation coding processes, and the specified bit rate; and

a main coding process for quantizing and coding the decoded stream with the optimum quantization step, and outputting a transcoded stream corresponding to the input stream.

10. The transcoding method of Claim 9 including, as said plural simulation coding processes, a first simulation coding process for coding the decoded stream with a first quantization step, and a second simulation coding process for coding the decoded stream with a second quantization step which is larger than the first quantization step.

11. The transcoding method of Claim 10 wherein:

in said quantization step derivation process, a transcoding error increasing rate which is the ratio of a variation in increment of coding error to a variation in the number of bits per coding unit in the transcoding process, is calculated on the basis of the number of bits per coding unit which is obtained in the first simulation coding process, the increment of coding error due to the first simulation coding process, the number of bits per coding unit which is obtained in the second simulation coding process, and the increment of coding error due to the second simulation coding process; and
either the first quantization step or the second quantization step is derived as an optimum quantization step, for each coding unit, according to the transcoding error increasing rate.

12. A transcoding method for subjecting an input stream obtained by coding an image signal to a transcoding process for each coding unit, thereby transforming the input stream into a transcoded stream having a bit rate lower than a specified bit rate, said method comprising:

a calculation process for calculating a target transcoding error increasing rate corresponding to one frame, on the basis of data obtained as the result of the transcoding process, said target transcoding error increasing rate being the ratio of an increment of coding error per coding unit which is generated in the transcoding process to the number of bits per coding unit which is reduced by the transcoding process;
a decoding process for decoding the input stream to generate a decoded stream;
a plurality of simulation coding processes having different quantization steps, for successively quantizing and coding the decoded stream for every coding unit;
a quantization step optimization process for deriving an optimum quantization step for each coding unit, on the basis of the numbers of bits per coding unit which are obtained in the respective simulation coding processes, the increments of coding error due to the respective simulation coding processes, and the target transcoding error increasing rate; and
a main coding process for quantizing and coding the decoded stream with the optimum quantization step, and outputting a transcoded stream corresponding to the input stream.

13. The transcoding method of Claim 12 including, as said plural simulation coding processes:

a first simulation coding process for quantizing and coding the decoded stream with a first quantization step;
a second simulation coding process for quantizing and coding the decoded stream with a second quantization step which is larger than the first quantization step; and
a third simulation coding process for quantizing and coding the decoded stream with a third quantization step which is larger than the second quantization step.

14. The transcoding method of Claim 13 wherein said quantization step derivation process includes:

a function derivation process for deriving, for each coding unit, a function which indicates the relationship between the quantization step corresponding to each coding unit and the transcoding error increasing rate which is the ratio of a variation in increment of coding error to a variation in the number of bits per coding unit in the transcoding process, on the basis of the first, second, and third numbers of bits per coding unit which are generated in the first, second, and third simulation coding processes, first, second, and third increments of coding error due to the first, second, and third simulation coding processes, and first, second, and third quantization steps used in the first, second, and third simulation coding processes; and
a quantization step decision process for deciding a quantization step in which the transcoding error increasing rate corresponding to each coding unit matches the target transcoding error increasing rate corresponding to said one frame, as an optimum quantization step for each coding unit, on the basis of the function.

15. The transcoding method of Claim 14 wherein, in said quantization step derivation process, only when the transcoding error increasing rate corresponding to each coding frame is smaller than the target transcoding error increasing rate corresponding to one frame, the quantization step used in the first simulation coding process is derived as an optimum quantization step, instead of the optimum quantization step decided in the quantization step decision process.

16. The transcoding method of Claim 15 wherein, in said quantization step derivation process, when the transcoding error increasing rate corresponding to each coding unit is not smaller than the target transcoding error increasing rate corresponding to one frame, a value larger than the second quantization step is derived as

the value of the optimum quantization step to be obtained in the quantization step decision process.

17. A transcoding system for transforming an input stream obtained by coding an image signal, into a transcoded stream having a bit rate lower than a specific bit rate, in a transcoding process, said system comprising:

a calculator for calculating the target number of bits for a target frame to be transcoded, on the basis of data obtained as the result of the transcoding process and a specified bit rate supplied from the outside of the system;
 a decoder for decoding the input stream to generate a decoded stream;
 a plurality of simulation encoders having different quantization steps, each encoder performing simulation coding for successively quantizing and coding the decoded stream for every coding unit;
 a quantization step derivation unit for deriving an optimum quantization step so that a difference between the bit rate of the transcoded stream and the specified bit rate is minimized, on the basis of the numbers of bits per coding unit which are obtained in the processes of the respective simulation encoders, the increments of coding error due to the processes of the respective simulation encoders, and the target number of bits for the target frame; and
 a main encoder for quantizing and coding the decoded stream with the optimum quantization step, and outputting a transcoded stream corresponding to the input stream.

18. The transcoding system of Claim 17 including:

as said plural simulation encoders,
 a first simulation encoder for subjecting the decoded stream to a first simulation coding process including a quantization process using a first quantization step, and outputting the number of bits per coding unit obtained by the simulation coding process, an increment of coding error due to the simulation coding process, and the first quantization step; and
 a second simulation encoder for subjecting the decoded stream to a second simulation coding process including a quantization process using a second quantization step which is larger than the first quantization step, and outputting the number of bits per coding unit obtained in the simulation coding process, an increment of coding error due to the simulation coding process, and the second quantization step; and
 a switch for selecting either the first quantization step or the second quantization step;
 wherein said quantization step derivation unit calculates a transcoding error increasing rate which is the ratio of a variation in increment of coding error to a variation in the number of bits per coding unit in the transcoding process, on the basis of the numbers of bits per coding unit which are obtained in the first and second simulation coding processes, and the increments of coding error due to the first and second simulation coding processes, and said quantization step derivation unit controls the switch so that it selects either the first quantization step or the second quantization step, according to the transcoding error increasing rate corresponding to each coding unit.

19. A transcoding system for subjecting an input stream obtained by coding an image signal to a transcoding process for each coding unit, thereby transforming the input stream into a transcoded stream having a bit rate lower than a specific bit rate, said system comprising:

a calculator for calculating a target transcoding error increasing rate corresponding to one frame, on the basis of data obtained as the result of the transcoding process, said target transcoding error increasing rate being the ratio of an increment of coding error per coding unit which is generated in the transcoding process to the number of bits per coding unit which is reduced by the transcoding process;
 a decoder for decoding the input stream to generate a decoded stream;
 a plurality of simulation encoders having different quantization steps, each encoder performing simulation coding for successively quantizing and coding the decoded stream for each coding unit;
 a quantization step derivation unit for deriving an optimum quantization step for each coding unit, on the basis of the numbers of bits per coding unit which are obtained in the processes of the respective simulation encoders, the increments of coding error due to the processes of the respective simulation encoders, and the target number of bits for the target frame; and
 a main encoder for quantizing and coding the decoded stream with the optimum quantization step, and outputting a transcoded stream corresponding to the input stream.

20. The transcoding system of Claim 19 including:

as said plural simulation encoders,
 a first simulation encoder for subjecting the decoded stream to a first simulation coding process including a

quantization process using a first quantization step, and outputting the number of bits per coding unit obtained in the simulation coding process, an increment of coding error due to the simulation coding process, and a first quantization step;
a second simulation encoder for subjecting the decoded stream to a second simulation coding process including a quantization process using a second quantization step which is larger than the first quantization step, and outputting the number of bits per coding unit obtained in the simulation coding process, an increment of coding error due to the simulation coding process, and the second quantization step; and
a third simulation encoder for subjecting the decoded stream to a third simulation coding process including a quantization process using a third quantization step which is larger than the second quantization step, and outputting the number of bits per coding unit obtained in the simulation coding process, an increment of coding error due to the simulation coding process, and the third quantization step.

21. The transcoding system of Claim 20 wherein said quantization step derivation unit comprises:

a calculation unit for calculating a transcoding error increasing rate which is the ratio of a variation in increment of coding error to a variation in the number of bits per coding unit in the transcoding process, on the basis of the numbers of bits per coding unit which are obtained in the processes of the respective simulation encoders, and the increments of coding error due to the processes of the respective simulation encoders; and
a quantization step selector for selecting one of the first, second, and third quantization steps, according to the result of comparison between the transcoding error increasing rate corresponding to each coding unit and the target transcoding error increasing rate.

22. The transcoding system of Claim 20 wherein said quantization step derivation unit includes:

a function derivation unit for deriving, for each coding unit, a function which indicates the relationship between the quantization step corresponding to each coding unit and the transcoding error increasing rate which is the ratio of a variation in increment of coding error to a variation in the number of bits per coding unit in the transcoding process, on the basis of the first, second, and third numbers of bits per coding unit which are generated by the first, second, and third simulation coding processes, first, second, and third increments of coding error due to the first, second, and third simulation coding processes, and the first, second, and third quantization steps used in the first, second, and third simulation coding processes; and
a quantization step calculator for calculating a quantization step in which the transcoding error increasing rate corresponding to each coding unit matches the target transcoding error increasing rate corresponding to one frame, as an optimum quantization step for each coding unit, on the basis of the function.

23. The transcoding system of claim 22 wherein said quantization step derivation unit includes:

a comparator for comparing the transcoding error increasing rate corresponding to each coding unit, with the target transcoding error increasing rate; and
a quantization step selector for selecting either the quantization step calculated by the quantization step calculator or the first quantization step, according to the result of comparison, and outputting the selected quantization step as an optimum quantization step.

24. A data storage medium containing a program for making a computer perform the transcoding method of Claim 9.

25. A data storage medium containing a program for making a computer perform the transcoding method of Claim 12.

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